VLF Up-Conve

Down below the long wave band there are many interesting signals to be heard, both natural and man-made. Adrian Knott G6KSN shows you how to make these signals audible on a communications receiver.

Some readers will doubtless possess a communications receiver. Whilst the majority of these sets perform very well in the h.f. band, most do not cover the frequency range below 500kHz. My interest in l.f./v.l.f. was aroused some years ago, when I found an article on decoding time transmissions from the atomic clock signal on MSF (on 60kHz).

Transmissions below 150kHz, potentially, have ranges of many thousands of kilometres. Signals in this band include radio navigation, standard frequencies and submarine communications. There are also naturally occurring phenomena between about 1kHz and 20-30kHz.

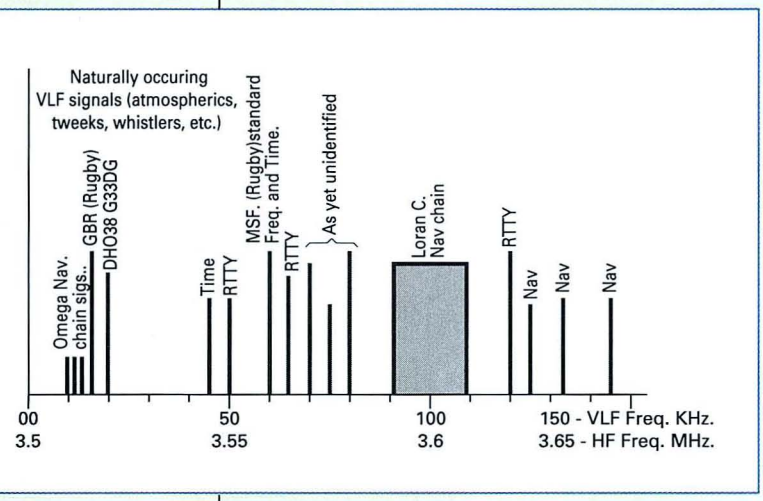

Fig. 1: Many, interesting signals are to be found below the long wave broadcast band. Using the up-converter described here, will make them audible in the 3.5MHz band as shown here.

The converter described here translates frequencies, in the range 500Hz to 150kHz, up into the 3.5MHz amateur band. A standard communications receiver will then allow you to listen in on this rather strange, and intriguing part of the electro-magnetic spectrum. If you look at **Fig. 1** you will see the range of signals.

Converting A Signal

Converting a 60kHz signal to 3.560MHz presents no real problem, but consider converting 10kHz up to 3.510MHz. With the converter local oscillator running at 3.5MHz and a conventional mixer all hell is let loose.

What we have done is to generate a very strong signal (the l.o.) only 10kHz away from our wanted (and very much weaker) signal. The result of the strong nearby signal, is to overload the front end of the communications receiver (and probably the i.f stages as well if a mediocre filter is used). This will result in our v.l.f. signal being lost under an enormous blocking signal.

The answer to the converter problem is to use a balanced mixer in the up-converter. Using a balanced mixer, results in a great reduction in the l.o. breakthrough. Even the most elementary of receivers should resolve the signal.

Final Design

The circuit in **Fig. 2** is the final design I arrived at. Since we are dealing with low frequencies, the r.f. amplifiers may be broad band and rolled off gently above 150kHz.

The v.l.f. signal from the loop is fed into the base of Tr1 via C1. This, in conjunction with the input impedance of the first stage, forms a high pass filter from about 500Hz upwards.

Stage gain is adjustable with R6, while capacitor C2 in the collector circuit of Tr1 reduces gain above 150kHz. Transistor Tr2 is another gain stage (C7 reduces gain above 150kHz), feeding the phase splitter Tr3. This phase splitter stage, Tr3, provides two signals of the same level but 180° out-of-phase with each other at outputs A and B.

The transistors, Tr5 and Tr6, form the balanced mixer, and must be matched for gain. The mixer, is symmetrical, but in addition, variable resistors, R25 and R27, improve the balance of the mixer, reducing l.o. breakthrough to a minimum.

Crystal Controlled

The converter oscillator is crystal controlled, and almost any parallel resonance fundamental crystal in the range 3-5MHz will do. Transistor Tr4 and its associated components form a crystal controlled, Colpitts style, local oscillator.

Capacitor C13 may be a 60pF trimmer if precise control of frequency is required. The output of the oscillator is taken from the emitter of Tr4, and fed into the mixer via identical networks C20, R23 and C21, R24.

The up-converted output from the mixer, is taken from the collectors of Tr5 and Tr6 via the output transformer T1. Transformer T1 primary is 24 turns, centre-tapped, of 0.27mm (32s.w.g.) enamelled copper wire. The secondary is 12 turns of the same wire.

In the prototype, T1 was wound on two ferrite beads, or you could use a T50-2 toroidal ferrite core. Both methods are shown in **Fig. 3**. Either method should prove satisfactory. The number, and ratio, of turns could be experimented with, to give best overall results.

Straightforward

Construction is quite straightforward, and the unit can be built on Veroboard or similar. Layout is not critical, as long as the following guide-lines are observed:

1) Keep the input of Tr1 as far away as possible from the output of Tr2.

2) Tr5 and Tr6, should be laid out on the board as symmetrically as possible and leads kept as short as possible.

3) If the oscillator is some distance from the input to the mixer then it should be fed via screened cable to avoid stray pick up.

4) The case of the crystal XL1 should be earthed by means of a short length of wire soldered firmly to the ground.

5) The finished projects should be mounted in a metal (preferably die-cast) box in order to minimise local oscillator radiation.

What Antenna

What kind antenna to use? A long-wire antenna has a very high impedance at these frequencies, unless it is several kilometres long. This form of antenna also seems to suffer from electrostatic breakthrough.

A resonant loop system was developed to interface into a load of about 10K. This reduces the *Q* of the loop for easier tuning, and accommodates the bandwidth of some of the signals found.

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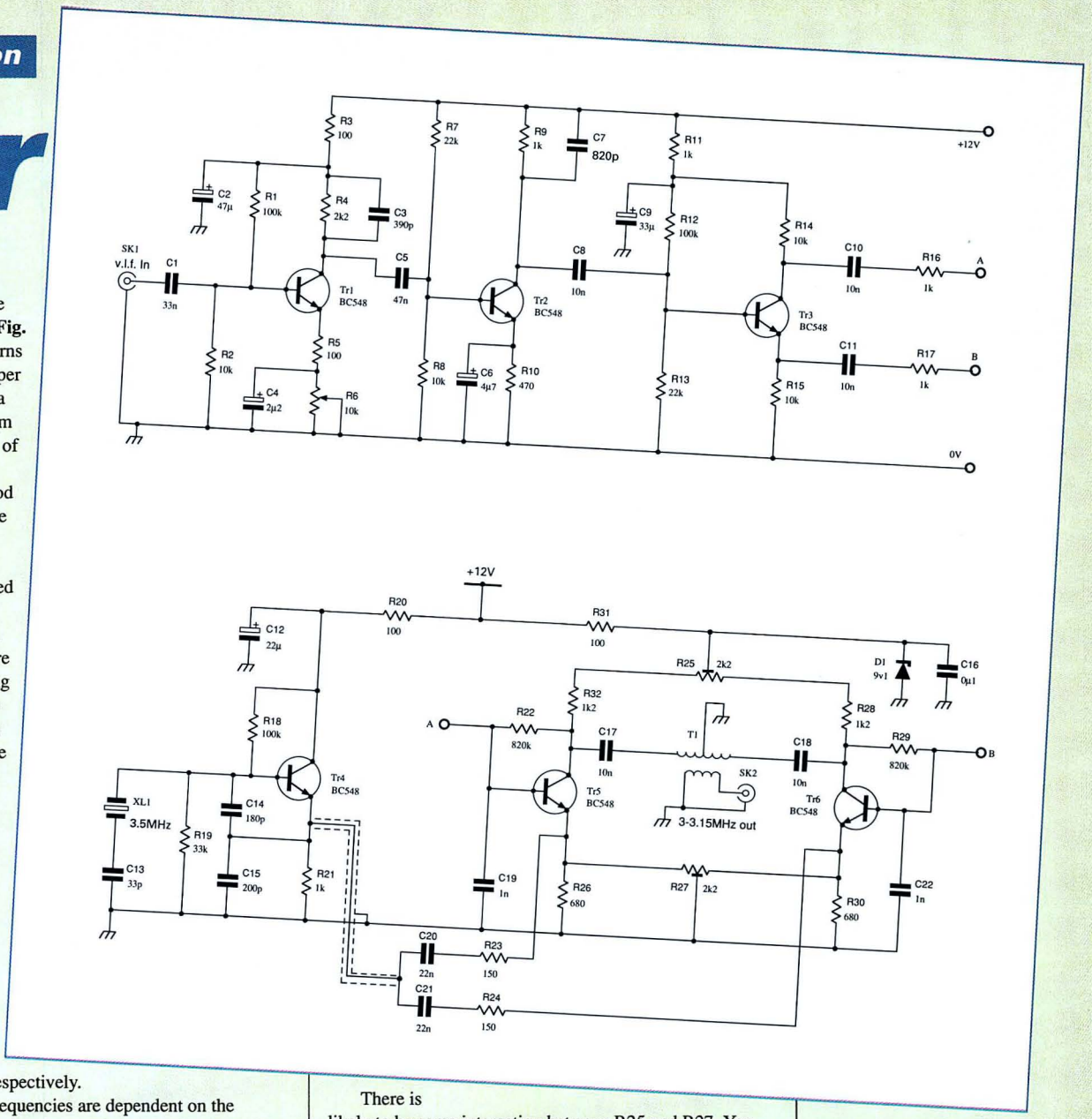

Fig. 2a: The circuit of the pre-amplifier and phase splitter section of the project.

Fig. 2b: The local oscillator and balanced mixer section. Points A and B couple to the similarly marked points in Fig. 2a.

The circuit of the antenna is shown in **Fig. 4**. It consists of 34 turns of 1mm covered copper wire, wound to give a loop diameter of 60cm (yes that's right - 24 of the old inches). A length of thin plywood or hardboard could be used to make up a former for the loop.

The loop is tapped to give 12 possible values of inductance. The tapping points are chosen so that moving along the coil by one tapping point, results in a frequency change of approximately 10%.

A 12-position switch S1 selects the appropriate tap. The parallel resonating capacitors, C_L and C_H are selected by S2, giving frequency coverage from 11.8 to 36.4kHz, with C_L, and 37.3 to 115.3kHz with C_H respectively.

Loop resonant frequencies are dependent on the settinng of S1 and S2. The two switches, and associated capacitors, may be mounted in the same case as the converter.

The loop itself could be attached to the converter case. Alternatively, the loop could be remotely mounted in an auxiliary case and connected to the converter by means of a short length of coaxial cable. The exact method of construction is a matter of personal preference, and the drawing of **Fig. 4** is merely a guide.

Setting Up

To start setting up, apply 12V to the unit, and check that the converter oscillator is working. To do this, tune a receiver to the oscillator frequency.

A short length of wire, connected to the emitter of Tr4, should create quite a strong signal for the receiver. If a known accurate receiver is available, and you have chosen to make C13 variable, then you can set the local oscillator frequency.

Set the b.f.o. on the communications receiver to centre point. Now trim C13 to give zero beat at 3.5MHz, or whatever other crystal frequency you have chosen. Remove the wire 'antenna' from Tr4, and connect the converter directly to the communications receiver by means of a good quality coaxial lead.

At this point the local oscillator signal may well give a reading of 60dB over S9 on the meter of the receiver. However, by careful adjustment, and re-adjustment, of R25 and R27, it should be possible to reduce the converter oscillator, to become less than an S5 signal.

There is likely to be some interaction between R25 and R27. You may have to carry this step out several times until no further improvement in local oscillator suppression can be achieved.

At the antenna, set S1 to position seven and select C_H (10nF) by means of S2. Then tune the communications receiver to 3.560MHz (or your chosen crystal frequency + 60kHz), where you should be able to hear a carrier pulsing at one second intervals.

At my location, this signal is endstopping on the S-meter. Now check that R6 alters the sensitivity of the unit, and that switching in C_L, or altering the tapping point, degrades the received signal on 60kHz. If all is well, then no further adjustments are necessary and the unit is ready for use.

Man-made Signals

The unit has been in use at my location for some time now, and some very strange signals have been heard. The omega signals around 12kHz are reasonably strong and GBR, DHO38, MSF and some other unidentifiable signals are received and indicated full-scale on the S-meter.

Since a lot of the signals present on v.l.f. are either data or RTTY, I think that a computer terminal/modem would be a useful addition to my shack. This is to be my next line of investigation.

Continued over

Natural Signals

Whistlers, Growlers, Tweeks and other types of naturally occurring v.l.f. signals, have also been heard. The levels of these atmospheric signals are at times, strong enough to obliterate the Omega Navigation beacons.

In many hours of continuous listening, the v.l.f. band has proved to be very interesting. The very low frequency band has proved to be a useful addition to my communications receiver, which lacked coverage of this fascinating part of the electromagnetic spectrum.

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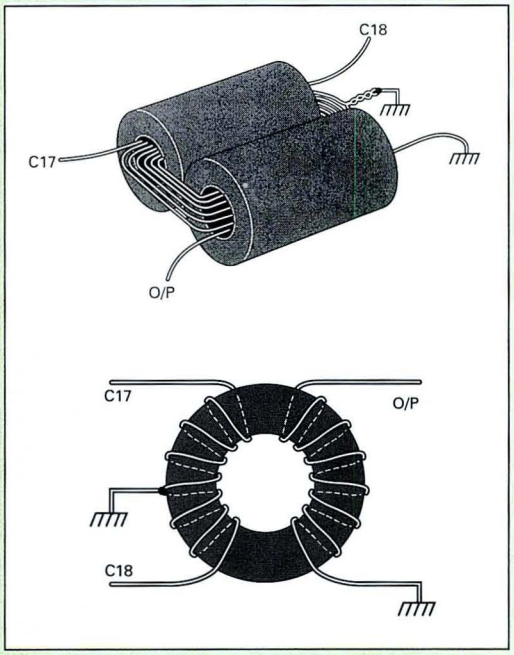

Fig. 3: Two possibilities for transformer T1.

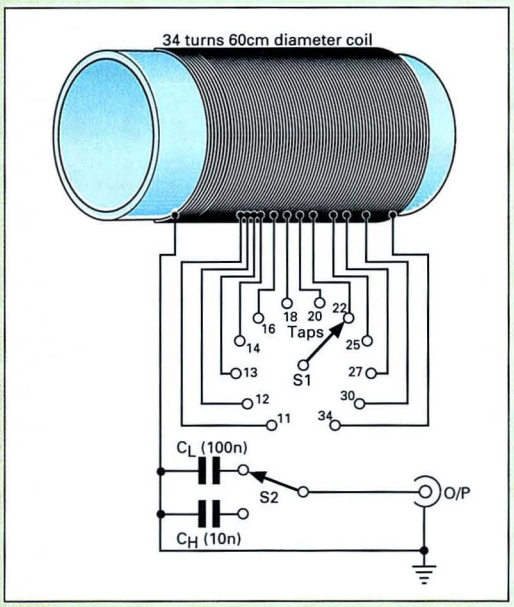

Fig.4: A representation of the antenna loop. The actual diameter of the loop is 600mm (24 inches).

Shopping List

Resistors

Carbon Film 0.25W 5%

100Ω	4	R3, 5, 20, 31
150Ω	2	R23, 24
470Ω	1	R10
680Ω	2	R26, 30
1kΩ	5	R9, 11, 16, 17, 21
1.2kΩ	2	R28, 32
2.2kΩ	1	R4
10kΩ	4	R2, 8, 14, 15
22kΩ	2	R7, 13
33kΩ	1	R19
100kΩ	3	R1, 12, 18
820kΩ	2	R22, 29

Variable miniature trimmer

2k2	2	R25, 27
10k	1	R6

Capacitors

Low voltage polystyrene

33pF	1	C13 (may be 60pF trimmer see text)
180pF	1	C14
200pF	1	C15 (220pF would also be suitable)
430pF	1	C3 (390 or 470pF might be suitable)
820pF	1	C7
1nF	2	C19, C22

Miniature polyester

10nF	6	C8, 10, 11, 17, 18, C_H
22nF	2	C20, 21
33nF	1	C1
47nF	1	C5
100nF	2	C16, C_L

Miniature electrolytic 16V working

2.2µF	1	C4
4.7µF	1	C6
22µF	1	C12
33µF	1	C9
47µF	1	C2

Semiconductors

BC548	6	Tr1-6
C9V1	1	D1

(any 500mW 9.1V zener diode would be suitable)

Miscellaneous

Crystal of 3.5MHz (or other suitable frequency), 1m of 0.27mm enamelled copper wire, about 70m of 1mm covered (enamelled) copper wire for the antenna coil, die-cast box to house the finished project. Various sockets to suit, miniature coaxial cable, and link-up wire, a single-pole 12-way switch for S1, and a single-pole change-over switch for S2.

Further Reading

'The Largest Antenna In The World' by Brian Dance in the September 1983 issue of *PW*, pages 40 /41. ‡
***Guide to Facsimile Stations* by Jeorg Klingenfuss, has frequencies for facsimile stations in the 50-145kHz band. ‡**
***Guide To Utility Stations* by Jeorg Klingenfuss, has frequencies for utility stations in the 50-145kHz band. ‡**
There is a group of people, who would like to utilise this band for communicating with caving research and rescue operation. For more information, contact Cave Radio and Electronics Group, c/o Davis Gibson, 21 Well House Drive, Leeds LS8 4BX. Tel: (0532) 481218.

‡ These items are available via the *PW* Book Service.